

4. SUMMARY OF FORECAST VERIFICATION

4.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities at initial, 12-, 24-, 48-, and 72-hour forecast periods are made against the final best track. The (scalar) track forecast, along-track and cross-track errors (illustrated in Figure 4-1) were calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, are included as Chapter 4. This section summarizes verification data this year and contrasts it with annual verification statistics from previous years.

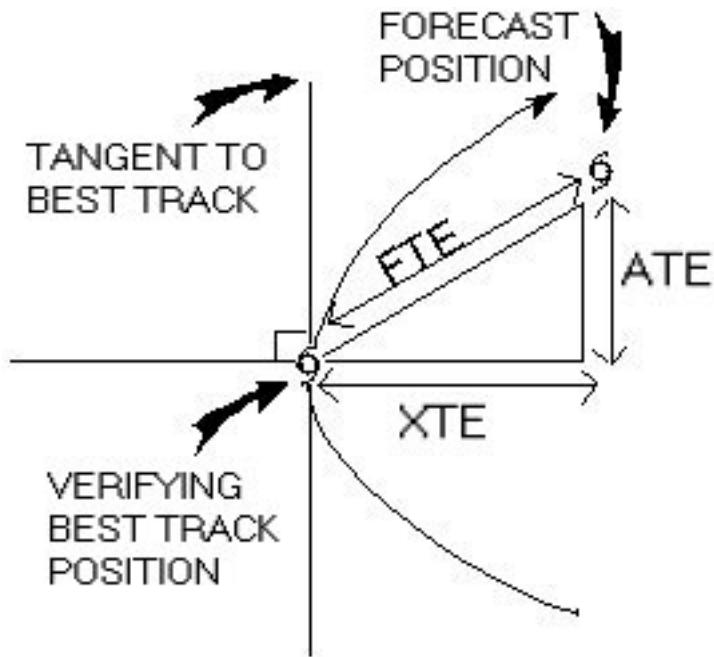


Figure 4-1. Definition of cross-track error (XTE), along-track error (ATE), and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of the best track) and the ATE is positive (ahead or faster than the best track). Adapted from Tsui and Miller, 1988.

4.1.1 WESTERN NORTH PACIFIC OCEAN

Table 4-1 includes mean track, along-track and cross-track errors from 1959, when JTWC was founded, until the present. Figure 4-2 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours since 1974.

Table 4-1 MEAN FORECAST TRACK ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959-2000

YEAR (Notes)	24-HOUR			48-HOUR			72-HOUR					
	TY (1)	TC (3)	CROSS TRACK (2)	ALONG TRACK (2)	TY (1)	TC (3)	CROSS TRACK (2)	ALONG TRACK (2)	TY (1)	TC (3)	CROSS TRACK (2)	ALONG TRACK (2)
1959	117*				267*							
1960	177*				354*							
1961	136				274							
1962	144				287				476			
1963	127				246				374			
1964	133				284				429			
1965	151				303				418			
1966	136				280				432			
1967	125				276				414			
1968	105				229				337			
1969	111				237				349			
1970	98	104			181	190			272	279		
1971	99	111	64		203	212	118		308	317	177	
1972	116	117	72		245	245	146		382	381	210	
1973	102	108	74		193	197	134		245	253	162	
1974	114	120	78		218	226	157		357	348	245	
1975	129	138	84		279	288	181		442	450	290	
1976	117	117	71		232	230	132		336	338	202	
1977	140	148	83		266	283	157		390	407	228	
1978	120	127	71	87	241	271	151	194	459	410	218	296
1979	113	124	76	81	219	226	138	146	319	316	182	214
1980	116	126	76	86	221	243	147	165	362	389	230	266
1981	117	124	77	80	215	221	131	146	342	334	219	206
1982	114	113	70	74	229	238	142	162	337	342	211	223
1983	110	117	73	76	247	260	164	169	384	407	263	259
1984	110	117	64	84	228	232	131	163	361	363	216	238
1985	112	117	68	80	228	231	138	153	355	367	227	230
1986	117	126	70	85	261	261	151	183	403	394	227	276
1987	101	107	64	71	211	204	127	134	318	303	186	198
1988	107	114	58	85	222	216	103	170	327	315	159	244
1989	107	120	69	83	214	231	127	162	325	350	177	265
1990	98	103	60	72	191	203	110	148	299	310	168	225
1991	93	96	53	69	187	185	97	137	298	287	146	229
1992	97	107	59	77	194	205	116	143	295	305	172	210
1993	102	112	63	79	205	212	117	151	320	321	173	226
1994**	96	105	56	76	172	186	105	131	244	258	152	176
1995	105	123	67	89	200	215	117	159	311	325	167	240
1996	85	105	56	76	157	178	89	134	252	272	137	203
1997	86	93	55	76	159	164	87	134	251	245	120	202

Table 4-1 MEAN FORECAST TRACK ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959-2000

1998	127	124	58	98	263	239	127	178	392	370	201	274
1999	88	106	59	74	150	176	102	119	225	234	139	155
2000	75	81	45	57	136	142	80	98	205	209	118	144
Averages (1978 - 2000)	104	112	64	79	207	215	122	151	321	323	183	226

1. Track errors were calculated for typhoons when intensities were at least 35kts at warning times

2. Cross-track and along-track errors were adopted by the JTWC in 1986. Right angle errors (used prior to 1986) were recomputed as cross-track errors after-the fact to extend the data base. See Figure 3-1 for the definitions of cross-track and along-track.

3. Mean forecast errors for all warned systems in Northwest Pacific.

*Forecast positions north of 35 degrees North latitude were not verified.

**1994 statistics were recalculated to resolve earlier Along and Cross-Track discrepancies.

4.1.2 NORTH INDIAN OCEAN

Table 4-2 includes mean track, along-track and cross-track errors for a 16-year period. Figure 4-3 shows mean track errors and a 5-year running mean of track errors at 24- and 48-hours since 1985, and at 72-hours since 1986.

Table 4-2 JTWC INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE NORTH INDIAN OCEAN 1985-2000

Initial Position	24-Hour				48-Hour				72-Hour					
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross
1985	53	31	30	122	102	53	8	242	119	194	0			
1986	28	52	16	134	118	53	7	168	131	80	5	269	189	180
1987	83	42	54	144	97	100	25	205	125	140	21	305	219	188
1988	44	34	30	120	89	63	18	219	112	176	12	409	227	303
1989	44	19	33	88	62	50	17	146	94	86	12	216	164	11
1990	46	31	36	101	85	43	24	146	117	67	17	185	130	104
1991	56	38	43	129	107	54	27	235	200	89	14	450	356	178
1992	191	35	149	128	73	86	100	244	141	166	62	398	276	218
1993	36	27	28	125	87	79	20	198	171	74	12	231	176	116
1994	60	25	44	97	80	44	28	153	124	63	13	213	177	92
1995	54	30	47	138	119	58	32	262	247	77	20	342	304	109
1996	135	33	123	134	94	80	85	238	181	127	58	311	172	237
1997	56	29	42	119	87	49	29	201	168	92	17	228	195	110
1998	80	20	55	106	84	51	34	198	135	106	17	262	188	144
1999	49	8	41	79	59	38	22	184	130	116	10	374	309	177
2000	31	15	24	61	47	26	16	85	69	37	1	401	399	38
(1985-2000)														
Avg	65	29	50	114	87	58	31	195	142	106	18	306*	232*	147*

*15 year average (1985 not available)

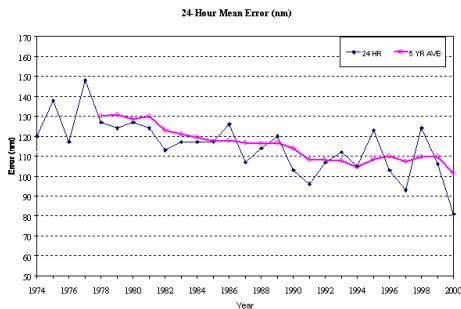


Figure 4-2a. Mean track forecast error (nm) and 5-year running mean for 24 hours for western North Pacific Ocean tropical cyclones from 1974-2000.

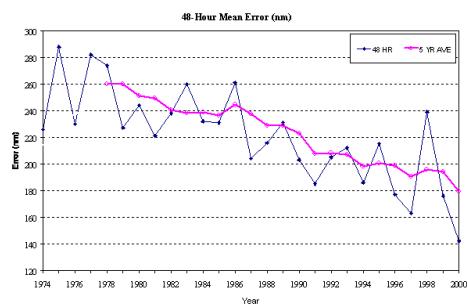


Figure 4-2b. Mean track forecast error (nm) and 5-year running mean for 48 hours for western North Pacific Ocean tropical cyclones from 1974-2000.

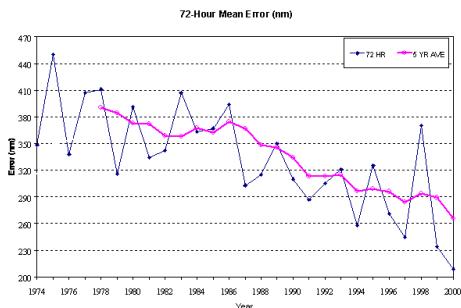


Figure 4-2c. Mean track forecast error (nm) and 5-year running mean for 72 hours for western North Pacific Ocean tropical cyclones from 1974-2000.

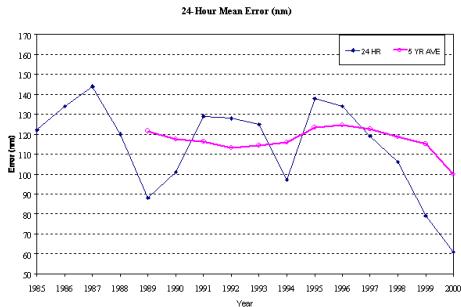


Figure 4-3a. Mean track forecast error (nm) and 5-year running mean for 24 hours for North Indian Ocean tropical cyclones from 1985-2000.

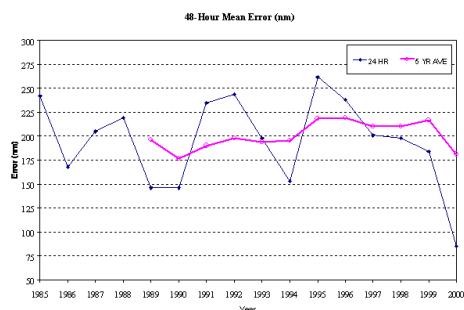


Figure 4-3b. Mean track forecast error (nm) and 5-year running mean for 48 hours, for North Indian Ocean tropical cyclones from 1985-2000.

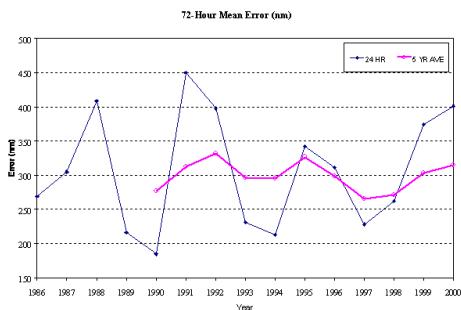


Figure 4-3c. Mean track forecast error (nm) and 5-year running mean for 72 hours for North Indian Ocean tropical cyclones from 1986-2000.

4.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS (SOUTHERN HEMISPHERE)

Table 4-3 includes mean track, along-track and cross-track errors for a 16-year period. Figure 4-4 shows mean track errors and a 5-year running mean of track errors at 24- and 48-hours since 1981, and at 72-hours since 1995.

Table 4-3 JTWC INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE SOUTHERN HEMISPHERE 1985-2000															
	Initial Position		24-Hour				48-Hour				72-Hour				
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross	
1985	306	36	257	134	92	79	193	236	169	132					
1986	279	40	227	129	86	77	171	262	169	164					
1987	189	46	138	145	94	90	101	280	153	138					
1988	204	34	99	146	98	83	48	290	246	144					
1989	287	31	242	124	84	73	186	240	166	136					
1990	272	27	228	143	105	74	177	263	178	152					
1991	264	24	231	115	75	69	185	220	152	129					
1992	267	28	230	124	91	64	208	240	177	129					
1993	257	21	225	102	74	57	176	199	142	114					
1994	386	28	345	115	77	68	282	224	147	134					
1995	245	24	222	108	82	55	175	198	144	108	53	291	169	190	
1996	343	24	298	125	90	67	237	240	174	129	46	277	221	133	
1997	561	24	499	109	82	72	442	210	163	135	150	288	248	175	
1998	329	26	305	111	85	52	245	219	169	108	81	349	261	171	
1999	348	17	322	113	80	64	245	226	159	132	59	286	198	164	
2000	384	12	313	72	47	45	245	135	84	86	58	180	94	139	
(1985-2000)															
Avg	308	28	261	120	84	68	207	230	162	129	75*	279*	199*	162*	

*6-year average

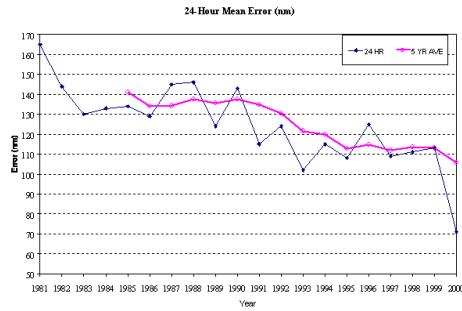


Figure 4-4a. Mean track forecast error (nm) and 5-year running mean for 24 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-2000.

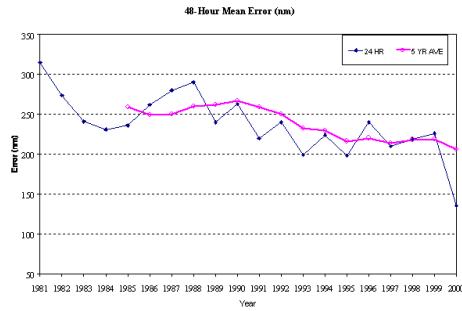


Figure 4-4b. Mean track forecast error (nm) and 5-year running mean for 48 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-2000.

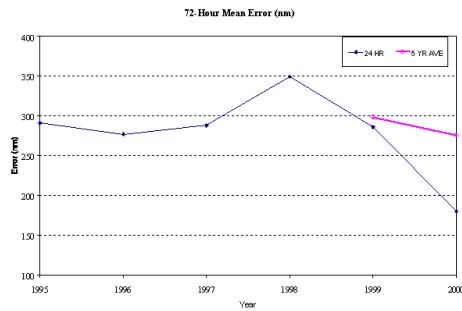


Figure 4-4c. Mean track forecast error (nm) at 72 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1995-2000.

4.2 TESTING AND RESULTS

A comparison of selected techniques is included in Table 4-4 for all western North Pacific tropical cyclones, Table 4-5 for North Indian Ocean tropical cyclones, and Table 4-6 for Southern Hemisphere tropical cyclones. For example, in Table 4-4 for the homogeneous comparison of the 12-hour mean forecast error between JTWC and NGPS, 324 cases were available. The average forecast error at 12 hours was 62 nm for NGPS and 48 nm for JTWC. The difference of 14 nm is shown in the lower right. Due to computational round-off, differences are not always exact.

Table 4-4 Error Statistics for Selected Objective Techniques

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP
JTWC	670	47						
	47	0						
NGPS	324	48	345	64				
	62	14	64	0				
CSUM	595	47	295	62	638	59		
	57	10	57	-5	59	0		
EGRR	2	13	2	62	1	36	2	77
	77	64	77	15	105	69	77	0
GFDN	248	47	0	0	228	59	0	248
	56	9	0	0	55	-4	0	56
JGSM	249	44	243	57	224	53	2	77
	47	3	48	-9	46	-7	33	-44
JTYM	230	43	2	74	211	55	0	0
	47	4	102	28	46	-9	0	46
CLIP	668	47	343	64	638	59	2	77
	57	10	58	-6	58	-1	43	-34

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP	NCON
JTWC	609	81							
	81	0							
NGPS	293	84	313	90					
	88	4	90	0					
CSUM	540	80	268	89	583	114			
	113	33	113	24	114	0			
EGRR	289	82	290	88	267	112	315	89	
	85	3	88	0	87	-25	89	0	
GFDN	222	76	0	0	204	115	0	0	222
	85	9	0	0	86	-29	0	0	85
JGSM	237	79	232	85	216	108	231	82	2
	74	-5	75	-10	72	-36	72	-10	183
JTYM	216	76	2	61	199	112	3	70	167
	79	3	125	64	78	-34	125	55	77
CLIP	607	81	311	90	583	114	310	89	221

Table 4-4 Error Statistics for Selected Objective Techniques

	110	29	111	21	111	-3	112	23	106	21	108	33	110	31	113	0
NCON	570	79	284	87	530	113	281	86	214	80	233	74	212	78	593	110
	78	-1	78	-9	78	-35	76	-10	75	-5	71	-3	71	-7	78	-32

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP
JTWC	544	114						
	114	0						
NGPS	261	116	280	120				
	119	3	120	0				
CSUM	479	112	239	121	524	165		
	164	52	163	42	165	0		
EGRR	2	101	2	132	1	302	2	254
	254	153	254	122	349	47	254	0
GFDN	201	102	0	0	184	167	0	0
	113	11	0	0	115	-52	0	0
JGSM	214	110	210	114	195	157	2	254
	103	-7	101	-13	100	-57	126	-128
JTYM	196	107	2	82	180	167	0	0
	117	10	145	63	116	-51	0	0
CLIP	542	114	279	120	524	165	2	254
	170	56	169	49	170	5	240	-14

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP	NCON
JTWC	470	142							
	142	0							
NGPS	218	141	242	151					
	149	8	151	0					
CSUM	417	142	206	154	469	216			
	214	72	207	53	216	0			
EGRR	221	142	223	146	209	211	251	146	
	146	4	143	-3	149	-62	146	0	
GFDN	172	133	0	0	159	224	0	0	173
	145	12	0	0	147	-77	0	0	145
JGSM	189	138	183	147	175	204	184	143	2
	135	-3	132	-15	133	-71	128	-15	508
JTYM	173	135	2	133	162	219	2	126	134
	149	14	200	67	149	-70	200	74	144
CLIP	470	142	242	151	469	216	247	148	173
	229	87	229	78	230	14	232	84	229
NCON	442	139	222	149	423	213	221	148	168
	130	-9	133	-16	135	-78	134	-14	126

72-HOUR MEAN FORECAST ERROR (NM)

Table 4-4 Error Statistics for Selected Objective Techniques

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP	NCON
JTWC	366	209							
	209	0							
NGPS	162	199	184	219					
	217	18	219	0					
CSUM	323	210	156	224	367	303			
	305	95	285	61	303	0			
EGRR	156	194	161	216	152	301	184	203	
	206	12	202	-14	209	-92	203	0	
GFDN	138	195	0	0	131	318	0	0	141 218
	212	17	0	0	217	-101	0	0	218 0
JGSM	145	202	135	213	135	303	136	198	1 550 155 197
	196	-6	193	-20	199	-104	188	-10	168 -382 197 0
JTYM	134	204	0	0	125	319	0	0	107 211 0 0 134 231
	231	27	0	0	231	-88	0	0	234 23 0 0 231 0
CLIP	366	209	184	219	367	303	182	205	141 218 154 194 134 231 448 344
	350	141	333	114	340	37	322	117	337 119 341 147 369 138 344 0
NCON	347	205	168	216	340	305	162	203	137 215 148 196 132 226 381 347 381 206
	200	-5	196	-20	207	-98	192	-11	188 -27 193 -3 195 -31 206 -141 206 0

Table 4-5 Error Statistics for Selected Objective Techniques

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	EGRR	GFDN	CLIP
JTWC	28	42			
	42	0			
NGPS	15	39	29	74	
	53	14	74	0	
EGRR	1	21	1	6	42
	42	21	42	36	42 0
GFDN	9	37	0	0	0 19 46
	46	9	0	0	0 46 0
CLIP	27	43	25	70	1 42 17 49 65 52
	47	4	53	-17	21 -21 42 -7 52 0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	EGRR	GFDN	CLIP
JTWC	24	61			
	61	0			
NGPS	14	58	27	86	
	53	-5	86	0	
EGRR	9	55	15	55	21 72
	68	13	58	3	72 0
GFDN	6	77	0	0	1 54 15 91

Table 4-5 Error Statistics for Selected Objective Techniques

	98	21	0	0	202	148	91	0		
CLIP	23	62	23	77	17	75	14	91	59	91
	82	20	91	14	67	-8	83	-8	91	0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	GFDN	CLIP	
JTWC	18	85			
	85	0			
NGPS	11	74	24	93	
	70	-4	93	0	
GFDN	4	119	0	0	12
	158	39	0	0	145
CLIP	17	87	20	77	11
	133	46	132	55	147
				124	-23
				138	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	EGRR	GFDN	CLIP	
JTWC	16	85				
	85	0				
NGPS	10	70	21	105		
	85	15	105	0		
EGRR	5	38	11	69	16	113
	109	71	88	19	113	0
GFDN	3	116	0	0	0	10
	185	69	0	0	0	185
CLIP	16	85	18	81	13	115
	177	92	183	102	144	29
					172	-13
					182	182
					0	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	EGRR	GFDN	CLIP	
JTWC	1	401				
	401	0				
NGPS	0	0	14	94		
	0	0	94	0		
EGRR	0	0	5	100	9	186
	0	0	149	49	186	0
GFDN	0	0	0	0	0	4
	0	0	0	0	0	199
CLIP	1	401	12	95	8	182
	341	-60	338	243	281	99
					350	350
					164	164
					314	314
					0	0

Table 4-6 Error Statistics for Selected Objective Techniques

12-HOUR MEAN FORECAST ERROR (NM)

Table 4-6 Error Statistics for Selected Objective Techniques

	JTWC	NGPS	EGRR	GFDN	CLIP	HPAC
JTWC	346	41				
	41	0				
NGPS	165	39	278	71		
	69	30	71	0		
EGRR	0	0	0	0	2	74
	0	0	0	0	74	0
GFDN	119	41	0	0	0	229
	50	9	0	0	0	49
CLIP	340	41	259	70	0	229
	64	23	104	34	0	49
HPAC	341	41	260	70	0	642
	57	16	60	-10	0	116
					55	670
					6	61
					-56	0
					60	
					124	
					124	
					0	
24-HOUR MEAN FORECAST ERROR (NM)						
	JTWC	NGPS	EGRR	GFDN	CLIP	HPAC
JTWC	313	72				
	72	0				
NGPS	148	69	255	110		
	104	35	110	0		
EGRR	171	69	230	111	299	83
	72	3	79	-32	83	0
GFDN	109	74	0	0	0	215
	79	5	0	0	0	76
CLIP	308	72	238	109	261	81
	113	41	154	45	148	67
HPAC	308	72	239	109	267	83
	106	34	111	2	110	27
					105	29
					112	-57
					114	0
36-HOUR MEAN FORECAST ERROR (NM)						
	JTWC	NGPS	EGRR	GFDN	CLIP	HPAC
JTWC	282	104				
	104	0				
NGPS	133	99	229	157		
	151	52	157	0		
EGRR	0	0	0	0	1	85
	0	0	0	0	85	0
GFDN	96	103	0	0	0	197
	105	2	0	0	0	104
CLIP	277	103	214	158	0	0
	173	70	218	60	0	197
HPAC	277	104	215	158	0	104
	155	51	159	1	0	557
					154	229
					50	584
					162	165
					-67	0

Table 4-6 Error Statistics for Selected Objective Techniques

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	EGRR	GFDN	CLIP	HPAC
JTWC	245	135				
	135	0				
NGPS	115	128	203	197		
	192	64	197	0		
EGRR	134	131	182	200	255	144
	132	1	137	-63	144	0
GFDN	87	136	0	0	0	178
	137	1	0	0	0	133
CLIP	240	134	188	199	218	140
	224	90	270	71	259	119
HPAC	240	134	190	198	225	145
	200	66	208	10	210	65
					204	71
					215	-72
					218	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	EGRR	GFDN	CLIP	HPAC
JTWC	58	180				
	180	0				
NGPS	25	165	139	273		
	246	81	273	0		
EGRR	28	172	122	272	202	194
	159	-13	184	-88	194	0
GFDN	25	182	0	0	0	139
	194	12	0	0	0	199
CLIP	58	180	131	277	173	191
	327	147	375	98	364	173
HPAC	58	180	133	275	180	194
	257	77	318	43	319	125
					311	112
					332	-57
					335	0